(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
4 January 2001 (04.01.2001)

PCT

(10) International Publication Number
WO 01/01213 A1

(51) International Patent Classification[7]: G05B 23/02

(21) International Application Number: PCT/US00/14798

(22) International Filing Date: 30 May 2000 (30.05.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/344,631 25 June 1999 (25.06.1999) US

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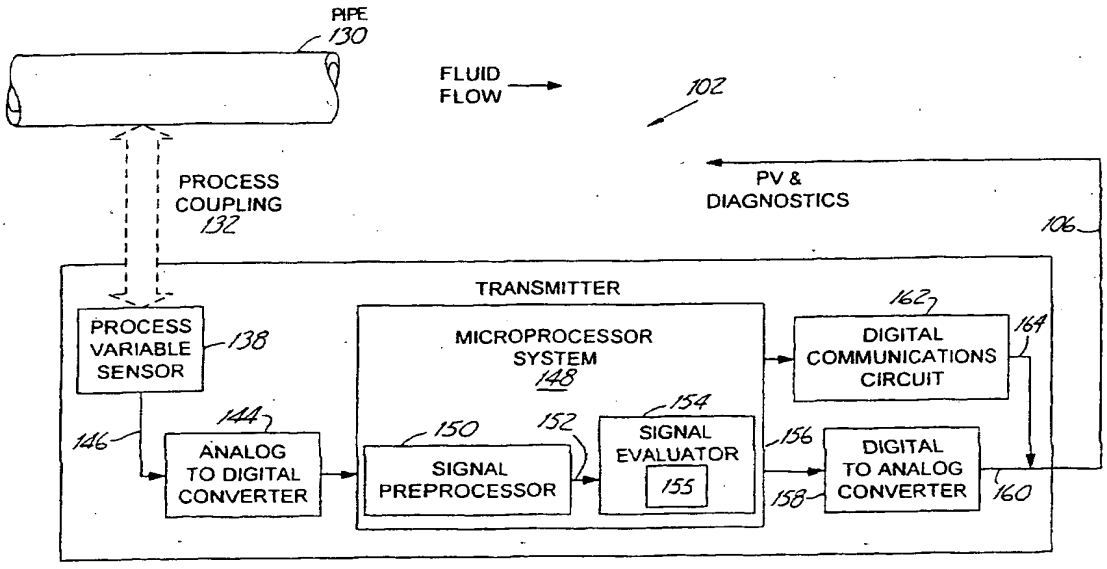
(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

[Continued on next page]

(54) Title: PROCESS DEVICE DIAGNOSTICS USING PROCESS VARIABLE SENSOR SIGNAL



(57) Abstract: Process device diagnostic is provided for diagnosing the condition of a process by receiving a process variable sensor signal (146). The process variable sensor (138) senses vibration noise signals (132) carried in a process fluid of the process. The vibration noise signals (132) are generated by the process, such as by operation of process control elements. The diagnostics isolates the process noise signals (132) in the process variable sensor signal (146) and evaluates the isolated signal to diagnose the process and the process devices.

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BNSDOCID: <WO_____0101213A1_I_>

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

PROCESS DEVICE DIAGNOSTICS USING PROCESS VARIABLE SENSOR SIGNAL

BACKGROUND OF THE INVENTION

The present invention relates to diagnostics of process devices (for use with industrial processes). More specifically, the invention relates to diagnostics of processes using a process variable sensor signal.

Process control devices are used in industrial process control systems to control a process. A control device is a field device which is used to control the process and includes pumps, valves, actuators, solenoids, motors, mixers, agitators, breaker, crusher, roller, mill, ball mill, kneader, blender, filter, cyclone, centrifuge, tower, dryer, conveyor, separator, elevator, hoist, heater, cooler or others. A valve controller includes a valve actuator coupled to a valve used to control flow of process fluid. A pump controller includes a motor controller or actuator coupled to a pump. Diagnostics of process control devices can be used to identify a failed control device or predict an impending failure.

Sensing vibrations is one method used to diagnose process control devices. A vibration sensor such as an accelerometer placed directly on a control device can be used to sense vibration noise signals generated by the device. Vibrations are isolated and evaluated by identifying those which exceed an amplitude threshold or which have an abnormal frequency which are indicative of an actual or impending failure. For example, sensors are placed on pump or motor housings, discharge valves, or flanges associated with the control device. Another known diagnostic method is a manual

inspection in which an operator listens for abnormal sounds from the control device.

These known methods rely on sensing vibrations at the process control device. The automated diagnostic techniques require additional sensors and circuitry to be included in the control device. There is thus a need for improved diagnostic technology which does not rely on additional components in the control device or the inaccurate and time consuming manual inspection of the prior art to isolate and evaluate vibration noise signals.

SUMMARY OF THE INVENTION

Diagnostics for diagnosing a process device isolates and evaluates vibration noise signals in the process fluid using a process variable sensor signal. The signal preprocessor isolates signal components in the sensor signal related to operation of the process and provides an isolated signal output. A signal evaluator provides a condition output related to a condition of the process control device as a function of the isolated signal. The diagnostic device is in a process control system, and vibrations from the process are transferred through process fluid to a process variable sensor used by the diagnostic device. A sensor input receives the process variable sensor signal from the process variable sensor. A portion of the sensor signal is related to the vibrations in the process which are carried in the process fluid.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of a typical fluid processing environment for the diagnostic device.

FIG. 2 is a block diagram of a differential pressure fluid flowmeter that diagnoses a condition of the process.

FIG. 3 is a graph of amplitude versus frequency versus time of a process variable signal.

FIG. 4 is a block diagram of a discrete wavelet transformation.

FIG. 5 is a graph showing signals output from a discrete wavelet transformation.

FIG. 6A is a simplified flow chart of a diagnostic device diagnosing a condition of a process.

FIG. 6B is a more detailed flow chart of a diagnostic device diagnosing a condition of a process.

FIG. 7 illustrates a magnetic flowmeter type diagnostic device.

FIG. 8 illustrates a vortex flowmeter type diagnostic device.

FIG. 9 illustrates a coriolis type diagnostic device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1, a typical environment for a diagnostic device in accordance with one embodiment of the invention is illustrated at 100. In FIG. 1, a diagnostic device, such as process transmitter 102 configured as a pressure transmitter, is shown connected to control system 104. Process transmitters can be configured to monitor one or more process variables associated with fluids in a process plant such as slurries, liquids, vapors and gasses in chemical, pulp, petroleum, gas, pharmaceutical, food and other fluid processing plants. The monitored process variables can be pressure, flow, level, temperature or other properties of fluids. A vibration sensitive process variable sensor

is one that can sense vibrations carried in the process fluid, such as a pressure sensor, a sensor in a coriolis flow meter, electrodes in a magnetic flow meter, a sensor in a vortex or ultrasonic flowmeter or others. Process transmitters include one or more sensors that can be either internal to the transmitter or external to the transmitter, depending on the installation needs at the process plant. Process transmitters generate one or more transmitter outputs that represent a sensed process variable or can also monitor the process using data received from remote sensors. Transmitter outputs are configured for transmission over long distance to a controller or indicator via communication bus 106. In typical fluid processing plants, communication bus 106 can be a 4-20 mA current loop that powers the transmitter, or a fieldbus connection, a HART® protocol communication or a fiberoptic connection to a controller, a control system or an output device. In transmitters powered by a two wire loop, power must be kept low to provide intrinsic safety in explosive atmospheres. Other types of communication busses can also be used such as either net operating with other protocols such as tcp/ip.

In FIG. 1, pump control device 108 and valve control device 110 are illustrated as examples of control devices and vibration noise sources. Control devices are actuated by control system 104 using communication bus 106 to control the process fluid. System 104 can be a maintenance computer, an enterprise planning or monitoring system or a computerized maintenance measurement system or a process control system. Control devices are also typically vibration noise sources. However, a vibration noise source is any element in a process which generates vibrations which are carried by

process fluid. Vibration noise signals are any vibration signal generated by a control device or which are generated by process fluid moving through the process system, such as vibrations due to cavitation or other flow or process related noise. Valve control device 110 includes a valve controller 112 which controls a supply of pressurized air to valve actuator 114 which in turn actuates valve 116. Pump control device includes motor 118 which actuates pump 120 to move process fluid through suction flange pipeline 122 and out discharge valve 124. Control devices and transmitters all couple to process piping 130 which carries process fluid. Vibration noise signals 132 generated by the process such as by operation of control devices, propagate through the process fluid and are sensed by a process variable sensor.

In FIG. 2, a block diagram shows one embodiment of a transmitter 102 configured as a diagnostic device in accordance with the invention. Examples of other diagnostic devices include control system 104, magnetic flowmeter 250 (FIG. 7), vortex flowmeter 260 (FIG. 8) and coriolis flowmeter 330 (FIG. 9). Transmitter 102 senses a process variable of process fluid in pipe 130 with process variable sensor 138. Transmitter 102 includes a process coupling 132 which couples a process variable sensor 138 to process fluid in pipe 130. For example, coupling 132 can comprise impulse lines 136 and flange 140 for transmitter 102, flow tube 252 for magnetic flowmeter 250, flow tube 264 and shedding bar 262 for vortex flowmeter 260, or flow tube 332 and measurement tubes 336 for coriolis flowmeter 330. Examples of process variable sensors 138 include a pressure sensor, electrodes 258 (FIG. 7), sensor 266 (FIG. 8), and coils 342 (FIG. 9). Analog to digital

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converter 144 receives sensor input 146 from process variable sensor 138 which is related to a process variable of the process fluid. Analog to digital converter 144 provides a digitized sensor signal to microprocessor system 148.

Microprocessor system 148 includes signal preprocessor 150 which is coupled to sensor input 146 through analog to digital converter 144 and isolates signal components in the sensor signal such as frequencies, amplitudes or signal characteristics which are related to operation of the process. Signal preprocessor 150 provides an isolated signal output 152 to signal evaluator 154. Signal preprocessor isolates a portion of the process variable signal by filtering, performing a wavelet transform, performing a Fourier transform, use of a neural network, statistical analysis, or other signal evaluation techniques. The isolated signal output is related to vibration noise signals 132 in the process fluid sensed by sensor 138. Signal evaluator 154 includes memory 155 and provides a condition output 156 which is related to a condition of the process. Signal evaluator 154 evaluates the isolated signal output 152 based upon a rule, fuzzy logic, a neural network, an expert system, a wavelet analysis or other signal evaluation technique. Process conditions include condition, diagnostic, health, or time to failure information related to valves, pumps, pump seals, discharge systems, actuators, solenoids, compressors, turbines, agitators, dampers, piping, fixtures, tanks, or other components of a process control system. Signal preprocessor 150 and signal evaluator 154 isolate and evaluate sensor signal components as shown in flow chart 200 of FIG. 6.

Microprocessor system 148 further calculates a process variable based upon the sensor signal input 146 in accordance with known techniques. A digital to analog converter 158 coupled to microprocessor system 148 generates an analog transmitter output 160 for coupling to communication bus 106. A digital communication circuit 162 generates a transmitter output 164. The analog output 160 and the diagnostic data 164 can be coupled to indicators or controllers as desired.

Signal preprocessor 150 is configured to isolate signal components which are related to vibration noise signals 132 in the process fluid. The signal components are isolated through signal processing techniques in which only desired frequencies or other signal characteristics such as amplitude are identified and an indication of their identification is provided on an isolated signal output 152. Depending upon the strength of noise signals 132 and their frequency, signal preprocessor can comprise a filter, for example a band pass filter, to generate the isolated signal output 152. For more sensitive isolation, advanced signal processing techniques are utilized such as a Fast Fourier transform (FFT) to obtain the spectrum of the sensor signal. In one preferred embodiment, signal preprocessor 150 comprises a wavelet processor which performs a wavelet analysis on the sensor signal as shown in FIGS. 3, 4 and 5 using a discrete wavelet transform. Wavelet analysis is well suited for analyzing signals which have transients or other non-stationary characteristics in the time domain. In contrast to Fourier transforms, wavelet analysis retains information in the time domain, i.e., when the event occurred.

Wavelet analysis is a technique for transforming a time domain signal into the frequency domain which, like a Fourier transformation, allows the frequency components to be identified. However, unlike a Fourier transformation, in a wavelet transformation the output includes information related to time. This may be expressed in the form of a three dimensional graph with time shown on one axis, frequency on a second axis and signal amplitude on a third axis. A discussion of wavelet analysis is given in On-Line Tool Condition Monitoring System With Wavelet Fuzzy Neural Network, by L. Xiaoli et al., 8 JOURNAL OF INTELLIGENT MANUFACTURING pgs. 271-276 (1997). In performing a continuous wavelet transformation, a portion of the sensor signal is windowed and convolved with a wavelet function. This convolution is performed by superimposing the wavelet function at the beginning of a sample, multiplying the wavelet function with the signal and then integrating the result over the sample period. The result of the integration is scaled and provides the first value for continuous wavelet transform at time equals zero. This point may be then mapped onto a three dimensional plane. The wavelet function is then shifted right (forward in time) and the multiplication and integration steps are repeated to obtain another set of data points which are mapped onto the 3-D space. This process is repeated and the wavelet is moved (convolved) through the entire signal. The wavelet function is then scaled, which changes the frequency resolution of the transformation, and the above steps are repeated.

Data from a wavelet transformation of a sensor signal from process variable sensor 138 is shown in FIG. 3. The data is graphed in three dimensions and forms a

surface 170. As shown in the graph of FIG. 3, the sensor signal includes a small signal peak at about 1 kHz at time t_1 and another peak at about 100 Hz at time t_2 due to vibration noise signal 132. Through subsequent processing by signal evaluator 154, surface 170 or portions of surface 170 are evaluated to provide condition output 156.

The continuous wavelet transformation described above requires extensive computations. Therefore, in one embodiment, signal preprocessor 150 performs a discrete wavelet transform (DWT) which is well suited for implementation in microprocessor system 148. One efficient discrete wavelet transform uses the Mallat algorithm which is a two channel sub-band coder. The Mallet algorithm provides a series of separated or decomposed signals which are representative of individual frequency components of the original signal. FIG. 4 shows an example of such a system in which an original sensor signal S is decomposed using a sub-band coder of a Mallet algorithm. The signal S has a frequency range from 0 to a maximum of f_{MAX}. The signal is passed simultaneously through a first high pass filter having a frequency range from 1/2 f_{MAX} to f_{MAX}, and a low pass filter having a frequency range from 0 to 1/2 f_{MAX}. This process is called decomposition. The output from the high pass filter provides "level 1" discrete wavelet transform coefficients. The level 1 coefficients represent the amplitude as a function of time of that portion of the input signal which is between 1/2 f_{max} and f_{MAX}. The output from the 0 - 1/2 f_{max} low pass filter is passed through subsequent high pass (1/4 f_{max} - 1/2 f_{max}) and low pass (0 - 1/4 f_{max}) filters, as desired, to provide additional levels (beyond "level 1") of discrete

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wavelet transform coefficients. The outputs from each low pass filter can be subjected to further decompositions offering additional levels of discrete wavelet transformation coefficients as desired. This process continues until the desired resolution is achieved or the number of remaining data samples after a decomposition yields no additional information. The resolution of the wavelet transform is chosen to be approximately the same as the sensor or the same as the minimum signal resolution required to monitor the vibration noise signal 132. Each level of DWT coefficients is representative of signal amplitude as a function of time for a given frequency range. Coefficients for each frequency range are concatenated to form a graph such as that shown in FIG. 3.

In some embodiments, padding is added to the signal by adding data to the sensor signal near the borders of windows used in the wavelet analysis. This padding reduces distortions in the frequency domain output. This technique can be used with a continuous wavelet transform or a discrete wavelet transform. "Padding" is defined as appending extra data on either side of the current active data window, for example, extra data points are added which extend 25% of the current window beyond either window edge. In one embodiment, the padding is generated by repeating a portion of the data in the current window so that the added data "pads" the existing signal on either side. The entire data set is then fit to a quadratic equation which is used to extrapolate the signal 25% beyond the active data window.

FIG. 5 is an example showing a signal S generated by sensor 138 and the resultant approximation

signals yielded in seven decomposition levels labelled level 1 through level 7. In this example, signal level 7 is representative of the lowest frequency DWT coefficient which can be generated. Any further decomposition yields noise. All levels, or only those levels which relate vibration noise signal 132, are provided as isolated signal 152 to signal evaluator 154. For example, depending on the particular system configuration and sensor type, levels 2, 3 and 5 can comprise the isolated signal 152 provided to signal evaluator 154.

Signal evaluator 154 evaluates the isolated signal 152 received from signal preprocessor 150 and in one embodiment, monitors an amplitude of a certain frequency or range of frequencies identified in isolated signal 152 and provides the condition output 156 if a threshold is exceeded. For example, if the isolated signal 152 comprises those components of sensor signal between 45 and 55 Hz, sensor evaluator 154 can provide condition output 156 if a threshold is exceeded indicative of a condition in the process such as a bearing failure in pump control device 108 or cavitation in valve control device 110. Signal evaluator can also comprise more advanced decision making algorithms such as fuzzy logic, neural networks, expert systems, rule based systems, etc. Commonly assigned U.S. Patent Application No. 08/623,569 describes various decision making systems which can be implemented in signal evaluator 154 and is incorporated herein by reference.

In FIG. 6A, a flow chart 180 of a method of diagnosis performed in a diagnostic device capable of receiving a process variable is shown. The algorithm starts at 182 and a process variable sensor signal is

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obtained. The process noise signal which is present in the process variable signal is isolated at 184. Next, the isolated process noise signal is evaluated at 186 and an output indicative of the process condition is provided at 188 in response to the evaluated isolated process noise signal. FIG. 6B is a more detailed flow chart 200 of the method of diagnosis. The algorithm starts at 202 and a process variable sensor signal is obtained. Components, X_1, X_2, X_3, X_4 . . . X_N are isolated at 204. (For simplicity, flow chart 200 shows only 4 components X_1 - X_4). If no components X_1-X_N are present, control is passed to block 202 and the process variable sensor signal is again obtained. At 206, 208, 210, 212 the isolated component X_1, X_2, X_3, X_4, respectively, are output. Each output is indicative of the presence of a particular signal component in the process variable sensor signal. The isolated components are evaluated at 214, 216, 218 and 220. In the signal evaluation illustrated in FIG. 6, a rule is used in which the isolated signal component is compared to a limit ($limit_1$, $limit_2$, $limit_3$, $limit_4$, respectively). If none of the limits have been exceeded by the respective isolated signal, the algorithm returns to 202 to obtain an updated process variable signal. If any limit has been exceeded, the algorithm proceeds to output $condition_1$, $condition_2$, $condition_3$, or $condition_4$ at 222, 224, 226 or 228, respectively. For example, component X_2 can comprise signal components of the process variable sensor signal between 45 and 55 Hz. If these components have a signal strength which is greater than a limit specified by $limit_2$, $condition_2$ is output which can indicate that a pump, for example, in the process is failing. Similarly, other components in the sensor signal indicate the

condition of other aspects of the process control system. If a single component is indicative of a condition of more than one aspect of the process, the output indicates that there are two possible conditions in the process. Further, the condition output is not necessarily tied to a specific failure and can simply indicate that a particular signal component has exceeded a threshold or has some other characteristic. In general, steps 202-212 are performed by signal preprocessor 150 of FIG. 2 and steps 214-226 are performed by signal evaluator 154. However, the steps of isolating and evaluating can be combined and performed simultaneously or by the same components in a diagnostic device.

In process control systems where there is a known process variation, for example, due to certain process activities, the variation can be modeled and thereby removed from the process variable signal to obtain the isolated sensor signal. In one aspect, wavelet transformation data is calculated and stored in memory 155 of signal evaluator 154 shown in FIG. 2 during normal operation of the process. This data represents a base "plane" of normal operation. The data can be collected at various times during the day, during a process cycle and during the year. When placed into normal use, signal evaluator 154 retrieves the stored wavelet transformation from memory 155 and compares the base plane data with information gathered through wavelet analysis during operation. For example, if signal evaluator 154 subtracts the base plane data from a current wavelet transformation, the resultant data represents only the anomalies occurring in the process. Such a subtraction process separates the process variations from abnormal vibration noise signals along

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with daily and seasonal variations in the signal. For example, the vibration sensor signal 146 may change during the day or over the course of a year due to environmental temperature changes and process activities. This separates the process signal from the vibration noise signal 132. During operation, a neural network can operate in microprocessor system 148 to monitor operation of the process and select the optimum model stored in memory 155. Coefficients related to operation of the model can be generated using a neural network or can be received over communication bus 106 during installation of transmitter 102 as provided for in various communication protocols. Examples of models include a first order model including dead time which is typically good for non-oscillatory systems, or second order models plus dead time which typically suffice for oscillatory processes. Another modeling technique is to use an adaptive neural network-fuzzy logic model. Such a hybrid system includes a neural network and fuzzy logic. The fuzzy logic adapts the model to variability of the process while the neural network models allow flexibility of the modeling to thereby adjust to changing processes. This provides a relatively robust model. The use of adaptive membership functions in the fuzzy logic model further allows the determination whether the particular model should be updated. The diagnostic device can operate with any appropriate type of signal evaluator such as one that includes life expectancy or diagnostic circuitry. Examples of such techniques are shown in the co-pending application Serial No. 08/744,980, filed November 7, 1996, entitled "DIAGNOSTICS FOR RESISTANCE BASED TRANSMITTER," which is incorporated by reference.

The process variable sensor 138 can be any type of process variable sensor which is capable of sensing vibrations in the process fluid. The process variable sensor should have a bandwidth and a frequency response or resolution sufficient to detect the desired vibration noise signals. Typically, this is between about 0 and about 200 Hz in a differential pressure based flow transmitter. One type of process variable sensor is a pressure sensor. A process variable pressure sensor having sufficient bandwidth is illustrated in U.S. Patent No. 5,637,802, issued June 10, 1997. Other components in the devices such as analog to digital converters must also have sufficient bandwidth, amplifiers and other elements in the input channel. FIG. 7 illustrates a magnetic flowmeter 250 having a process variable sensor provided by electrodes 258. Flowmeter 250 includes flow tube 252 coupled to electronics housing 254. In a magnetic flowmeter, coils 256 generate a magnetic field in flow tube 252. The flow of process fluid through the resultant magnetic field develops an electric potential between electrodes 258 which provide a process variable sensor signal. Vibration signals 132 in the fluid change the flow rate and can be sensed by electrodes 258. Typical frequency response of magnetic flowmeters are 0-75 Hz or higher.

FIG. 8 illustrates a vortex flowmeter 260 having a process variable sensor provided by sensor 266. Vortex flowmeter 260 includes a shedding bar 262 mounted in flow tube 264 and coupled to fourth sensor 266. A flow of process fluid through flow tube 264 causes shedding bar 262 to move about pivot axis 268. This movement causes a force 270 to be transferred to sensor 266 which provides a process variable sensor signal. The

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frequency of this force is related to the flow through flow tube 264. Noise vibration signals 132 are also transferred to sensor 266 for use with the signal preprocessor 150 and signal evaluator 154 shown in FIG. 2. Vortex flowmeters typically have a frequency response of between about 0 and 10 KHz or higher.

FIG. 9 illustrates a coriolis flowmeter 330 process variable sensor provided by coils 342 and which includes a flow tube 332 and meter electronics 334. Measurement tubes 336 coupled to flow tube 332. A drive coil 340 vibrates tubes 336 in response to a drive signal and sense elements which include sense coils 342 and sense magnets 344 provide left and right velocity signals related to the resultant vibration of tubes 336. Flow through the tubes 336 cause tubes 336 to pivot in a manner which is sensed by coils 342. The outputs from coils 342 are related to flow through tubes 336 and provide a process variable sensor signal. Vibration noise signals 132 can also be sensed by coils 342 and provided to signal preprocessor 140 shown in FIG. 2. Coriolis meters typically have a very wide frequency response which can sense vibrations at very high frequencies.

Other types of process variable sensors include an ultrasonic or radio frequency receiver in a level gauge or an ultrasonic receiver in a ultrasonic level sensor. For example, transmitter 102 can comprise an ultrasonic flowmeter or level gauge and sensor 138 is an ultrasonic sensor. Additionally, control devices such as valve controllers can include process variable sensors.

Although the invention has been described with reference to preferred embodiments, workers skilled in

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the art will recognize that changes can be made in form and detail without departing from the spirit and scope of the invention. The invention can be practiced in software rather than in any of a number of places in a process control system such as in a field mounted device or even a system controller. Furthermore, modern digital protocol such as fieldbus, profibus and others allow for the software which practices the invention to be communicated between elements in a process control system, and also provide for process variables to be sent in one transmitter and then sent to the software which is resident in a different piece of equipment. For example, various function blocks of the invention have been described in terms of circuitry, however, many function blocks may be implemented in other forms such as digital and analog circuits, software and their hybrids. When implemented in software, a microprocessor performs the functions and the signals comprise digital values on which the software operates. A general purpose processor programmed with instructions that cause the processor to perform the desired process elements, application specific hardware components that contain circuit wired to perform the desired elements and any combination of programming a general purpose processor and hardware components can be used. Deterministic or fuzzy logic techniques can be used as needed to make decisions in the circuitry or software. Because of the nature of complex digital circuitry, circuit elements may not be partitioned into separate blocks as shown, but components used for various functional blocks can be intermingled and shared. Likewise with software, some instructions can be shared as part of several functions and be intermingled with unrelated instructions within

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the scope of the invention. A diagnostic device can be any device (or a combination of devices such as devices which share information to arrive at a conclusion) which receives a process variable signal including a process monitoring system, a personal computer, a control system, a portable communicator, a controller or a transmitter. U.S. Patent No. 5,754,596 describes a technique for transmitting stored data which has been stored in a field device such that the stored data can have a higher bandwidth than would be possible if data were transmitted at the update rate of the communication protocol. Any type of process variable sensor which is sensitive to a process noise signal can be used with the diagnostic device of the invention.

WHAT IS CLAIMED IS:

1. A diagnostic device for use in a process control system, comprising:

a sensor signal input, the sensor signal related to a process variable of a process fluid of a process, the process variable sensed by a process variable sensor;

a signal preprocessor coupled to the sensor input having an isolated signal output comprising signal components in the sensor signal related to operation of the process; and

a signal evaluator coupled to the isolated signal output having a condition output related to a condition of the process.

2. The diagnostic device of claim 1 wherein the sensor signal has a frequency response of at least about 50 Hz.

3. A transmitter including the diagnostic device of claim 1.

4. The diagnostic device of claim 1 wherein the process variable sensor comprises a pressure sensor.

5. The diagnostic device of claim 1 wherein the process variable sensor comprises electrodes in a magnetic flowmeter.

6. The diagnostic device of claim 1 wherein the process variable sensor comprises a sensor in a vortex flowmeter.

7. The diagnostic device of claim 1 wherein the process variable sensor comprises a sensor in a coriolis flowmeter.

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8. The diagnostic device of claim 1 wherein the signal evaluator comprises a threshold level.

9. The diagnostic device of claim 8 wherein the signal preprocessor isolates a frequency range and the signal evaluator compares an amplitude of the isolated frequency range to the threshold level.

10. The diagnostic device of claim 1 wherein the isolated signal output comprises a frequency range of the sensor signal.

11. The diagnostic device of claim 1 wherein the sensor signal has a frequency of between about 0 Hz and about 200 Hz.

12. The diagnostic device of claim 1 wherein the signal preprocessor comprises a wavelet preprocessor coupled to the sensor signal.

13. The diagnostic device of claim 12 wherein the wavelet processor performs wavelet transform.

14. The diagnostic device of claim 13 wherein the wavelet transform comprises a discrete wavelet transform.

15. The diagnostic device of claim 1 wherein the signal preprocessor comprises a filter.

16. The diagnostic device of claim 1 wherein the condition relates to operation of a process control device.

17. The diagnostic device of claim 1 wherein the diagnostic device is implemented in a process monitor.

18. The diagnostic device of claim 1 wherein the diagnostic device is implemented in a control system.

19. The diagnostic device of claim 1 wherein the diagnostic device couples to a communication bus.

20. The diagnostic device of claim 19 wherein the communication bus comprises a two-wire loop.

21. The diagnostic device of claim 20 wherein the diagnostic device is fully powered with power received from the two-wire loop.

22. The diagnostic device of claim 1 wherein the isolated signal output relates to a vibration noise signal carried in process fluid of the process.

23. The diagnostic device of claim 1 wherein the process variable sensor comprises a sensor in an ultrasonic flowmeter.

24. The dianostic device of claim 1 wherein the condition of the process is related to condition of a process device selected from the group of devices consisting of valves, pumps, pump seals, discharge systems, actuators, solenoids, compressors, turbines, agitators, dampers, piping, fixtures and tanks

25. A diagnostic method performed in a process control environment, the method comprising:

obtaining a process variable sensor signal;

isolating a process noise signal in the process variable sensor signal; and

evaluating the isolated signal and providing a condition output related to the process.

26. The method of claim 25 wherein isolating comprises filtering the process variable sensor signal.

27. The method of claim 25 wherein isolating comprises performing a wavelet transformation on the process variable sensor signal.

28. The method of claim 27 wherein performing a wavelet transformation comprises performing a wavelet transformation.

29. The method of claim 28 wherein performing a wavelet transform comprises performing a discrete wavelet transform.

30. The method of claim 25 wherein evaluating comprises comparing the isolated signal to a threshold.

31. The method of claim 25 wherein evaluating comprises applying the isolated signal to a neural network.

32. The method of claim 25 wherein evaluating comprises applying a rule to the isolated signal.

33. The method of claim 25 wherein the process variable sensor signal comprises a pressure sensor signal.

34. The method of claim 25 wherein the process variable sensor signal comprises a sensor output from a coriolis flowmeter.

35. The method of claim 25 wherein the process variable sensor signal comprises a sensor output from a vortex flowmeter.

36. The method of claim 25 wherein the process variable sensor signal comprises electrode outputs from a magnetic flowmeter.

37. The method of claim 25 wherein the process variable sensor signal comprises an output from a sensor in a coriolis flowmeter.

38. The method of claim 25 wherein the process variable sensor signal has a bandwidth of at least about 50 Hz.

39. The method of claim 25 wherein the condition output relates to a condition of a process control device.

40. The method of claim 25 including fully powering the diagnostic device with power from a two-wire loop.

41. A process transmitter implementing the method of claim 25.

42. A process control system implementing the method of claim 25.

43. A process control device implementing the method of claim 25.

44. A process monitor implementing the method of claim 25.

45. A computer-readable medium having stored thereon instructions executable by a microprocessor system in a diagnostic device to diagnose condition of a process, the instructions comprising:

obtaining a process variable sensor signal;

isolating a process noise signal in the process variable sensor signal;

evaluating the isolated signal; and

outputting the process condition in response to the evaluation.

46. A diagnostic device for use in a process control system, comprising:

a sensor signal input, the sensor signal related to a process variable of a process fluid of a process, the process variable sensed by a process variable sensor;

signal preprocessing means for isolating signal components in the sensor signal related to operation of the process and providing an isolated signal output; and

signal evaluating means for diagnosing a condition of the process.

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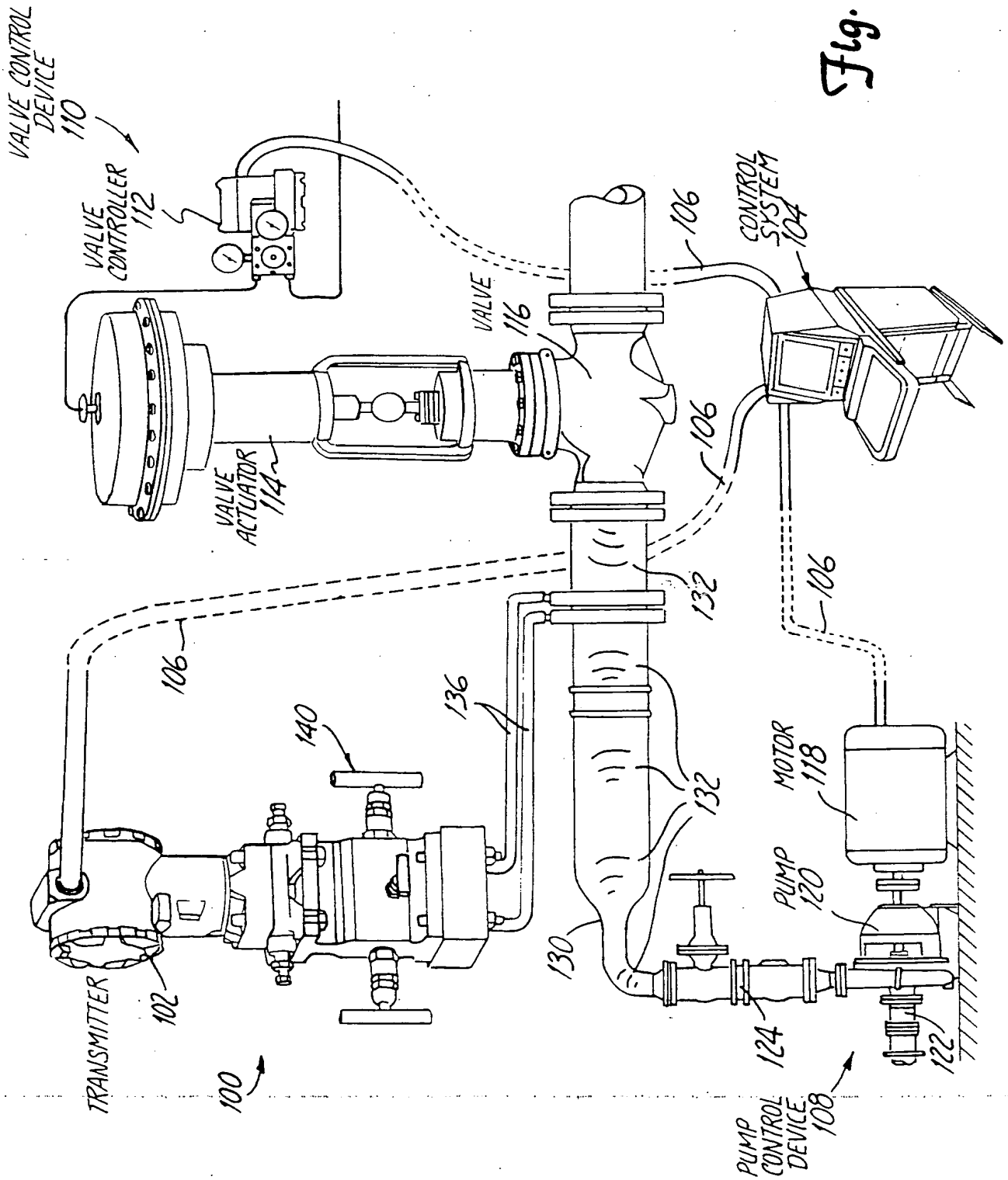

Fig. 1

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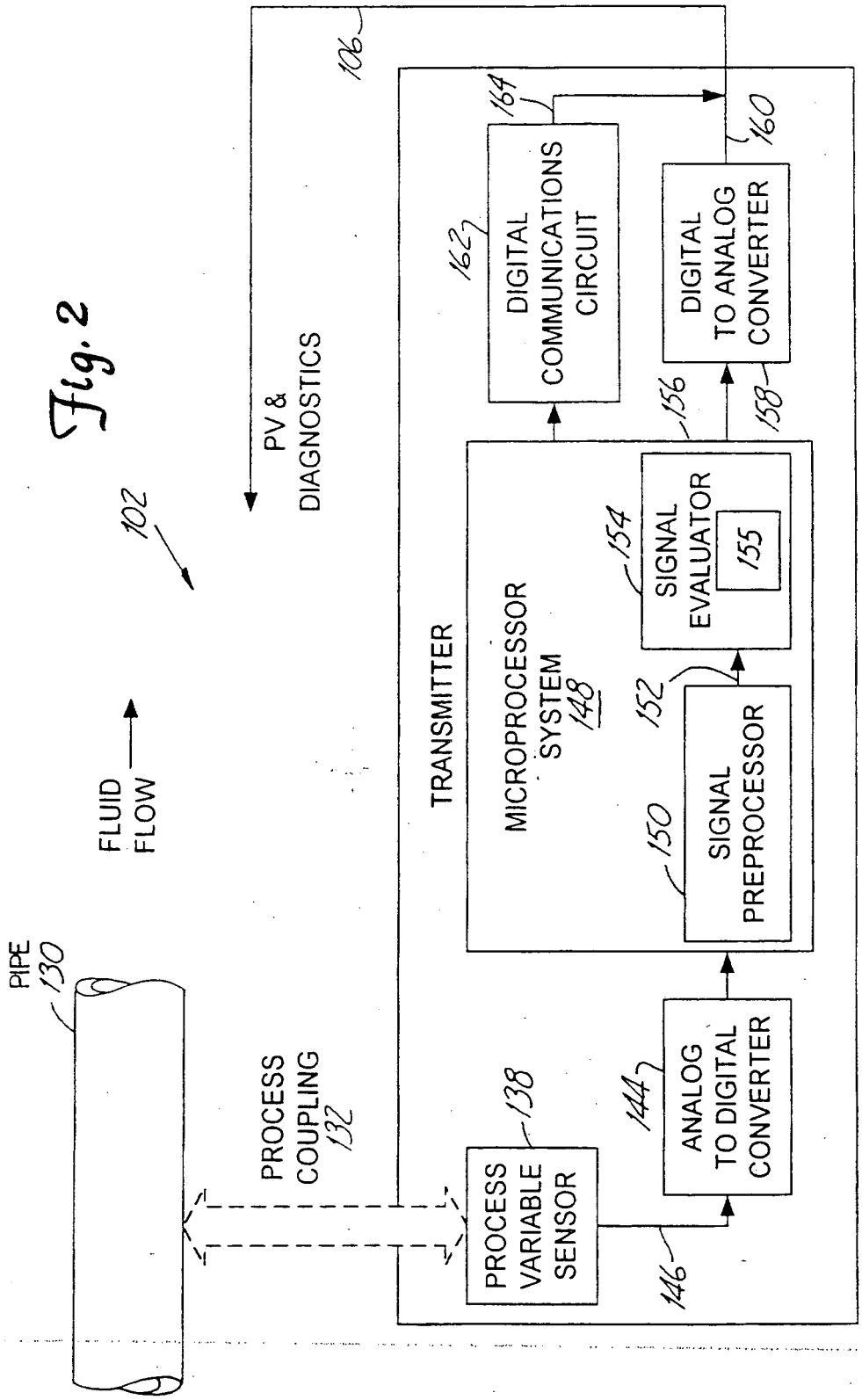

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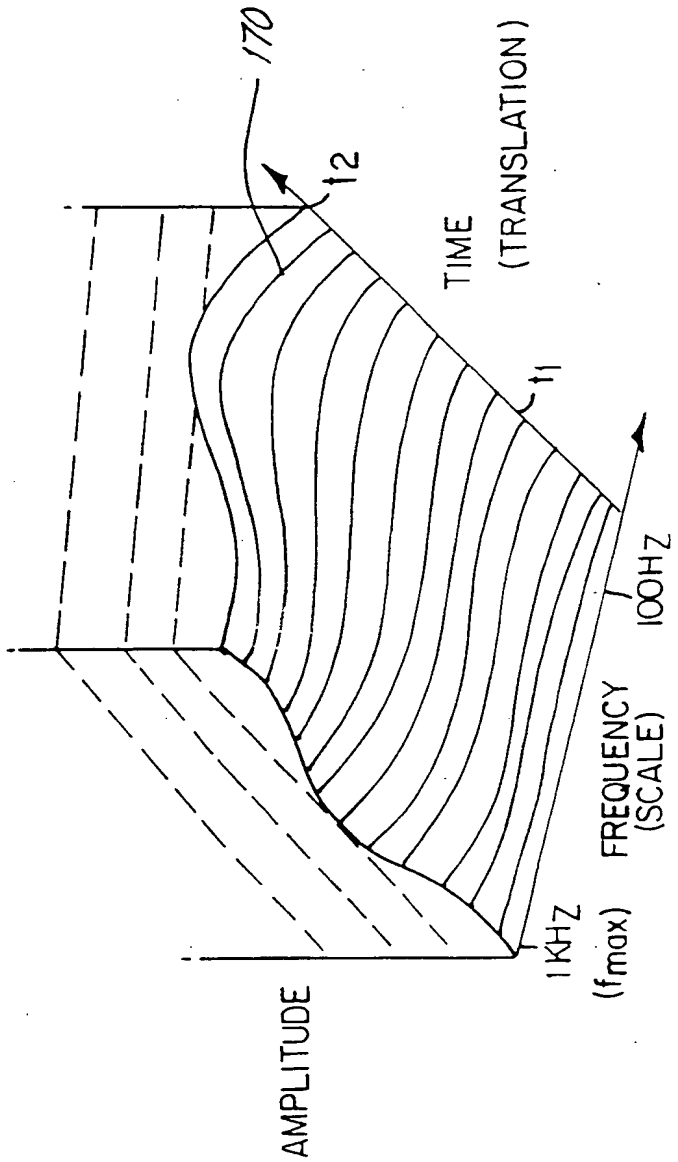

Fig. 3

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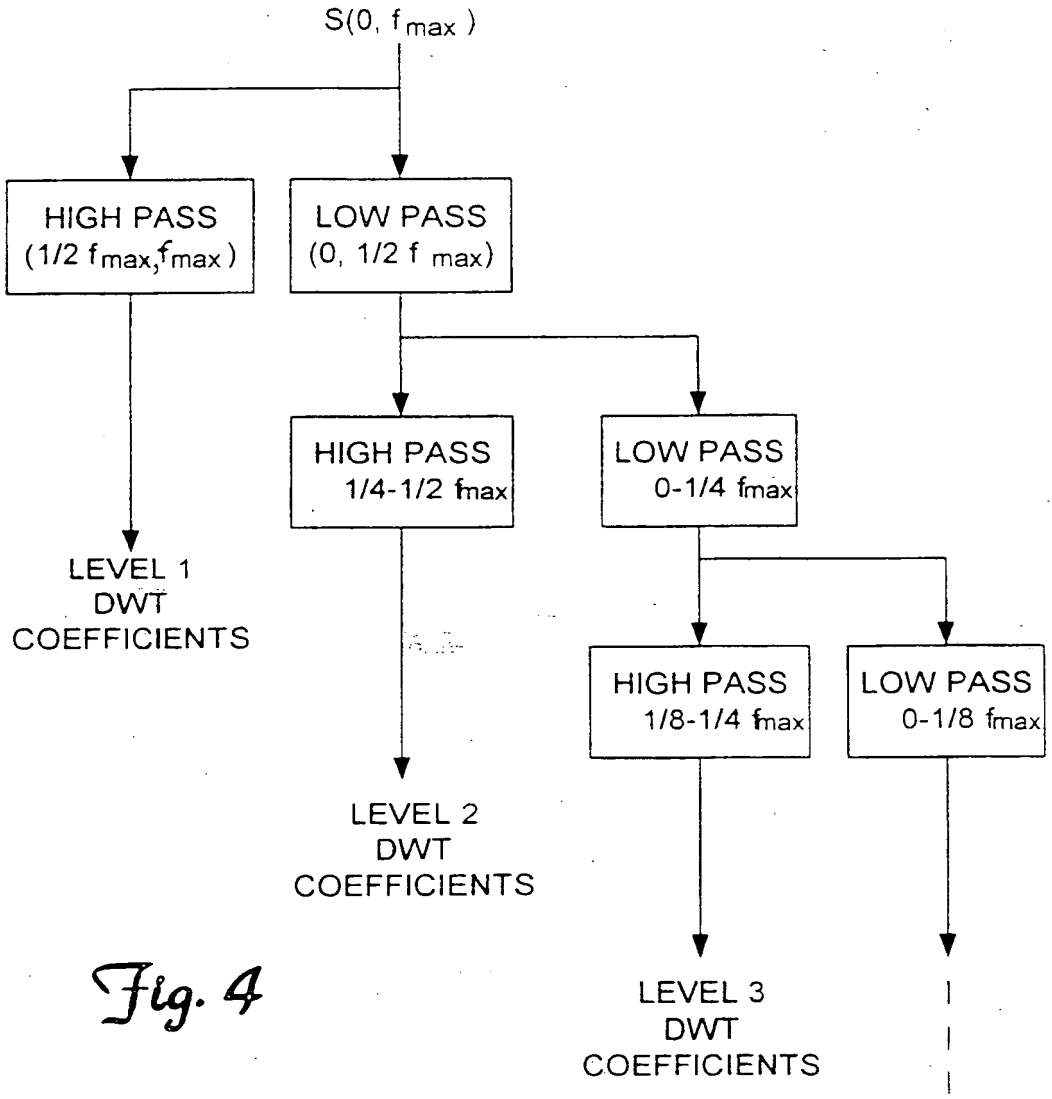

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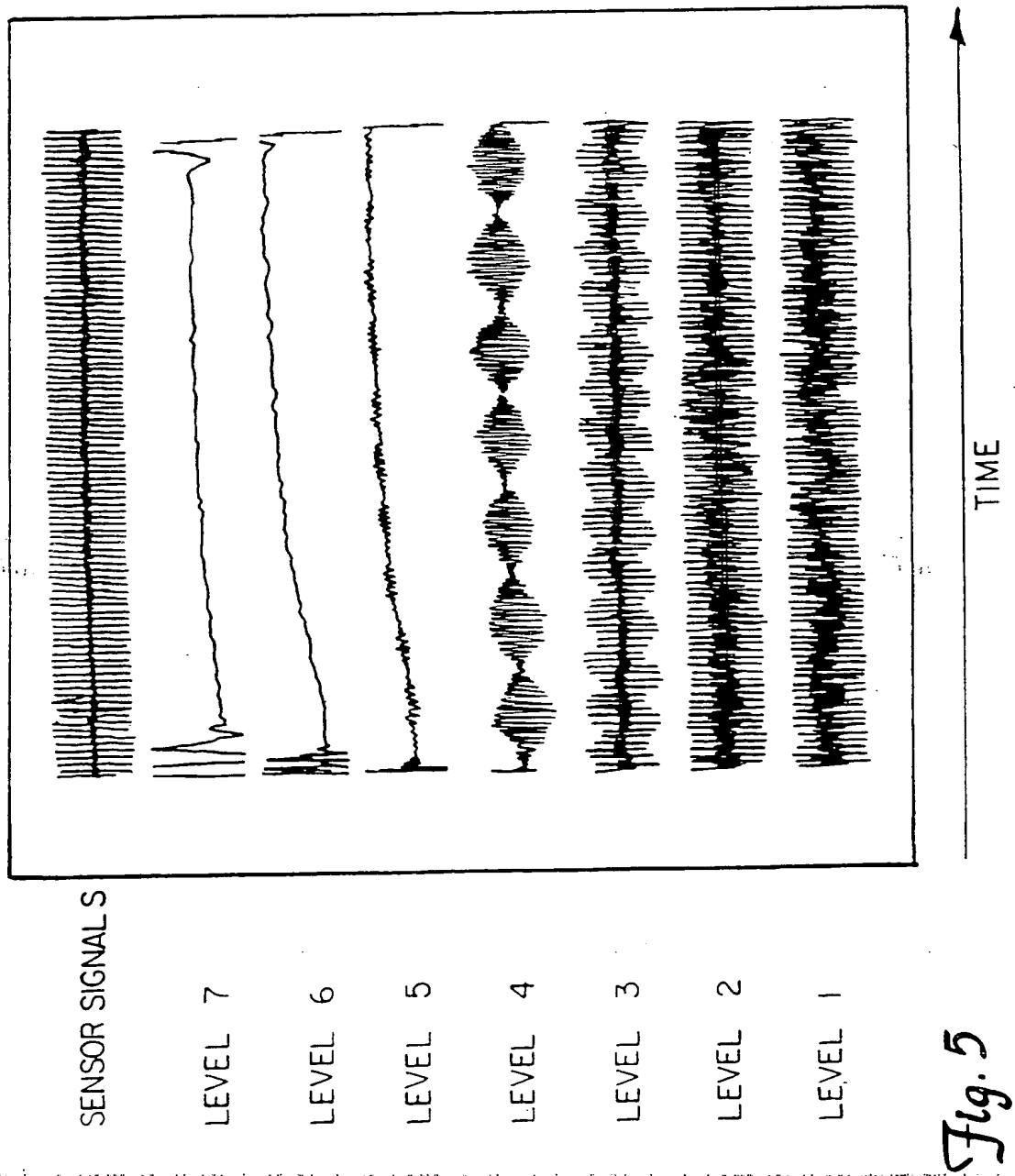

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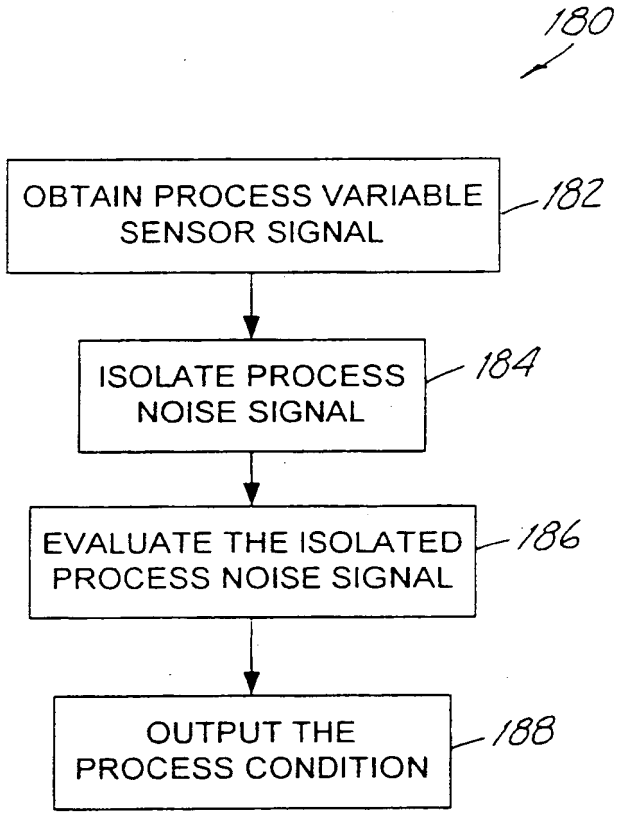

Fig. 6A

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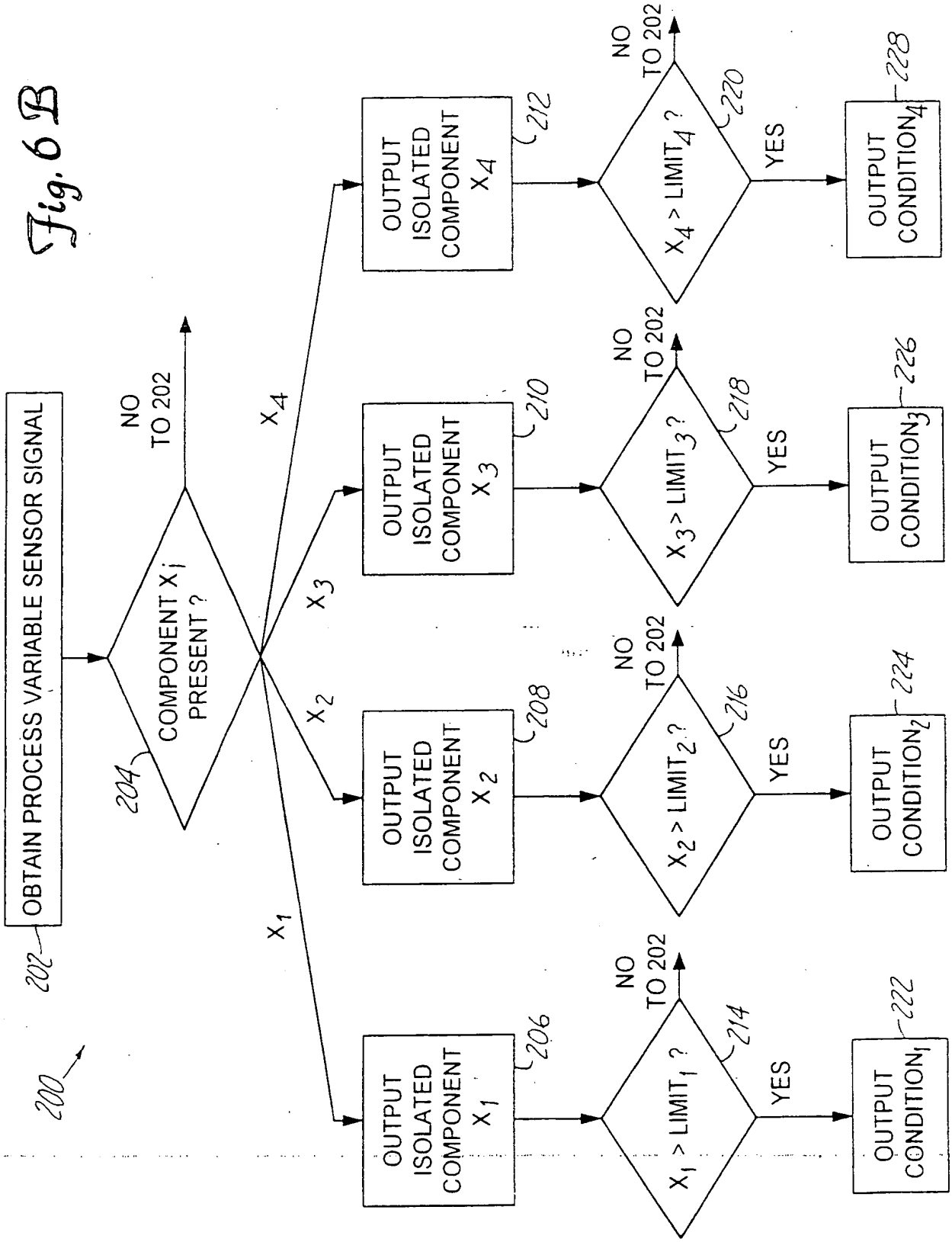
Fig. 6B



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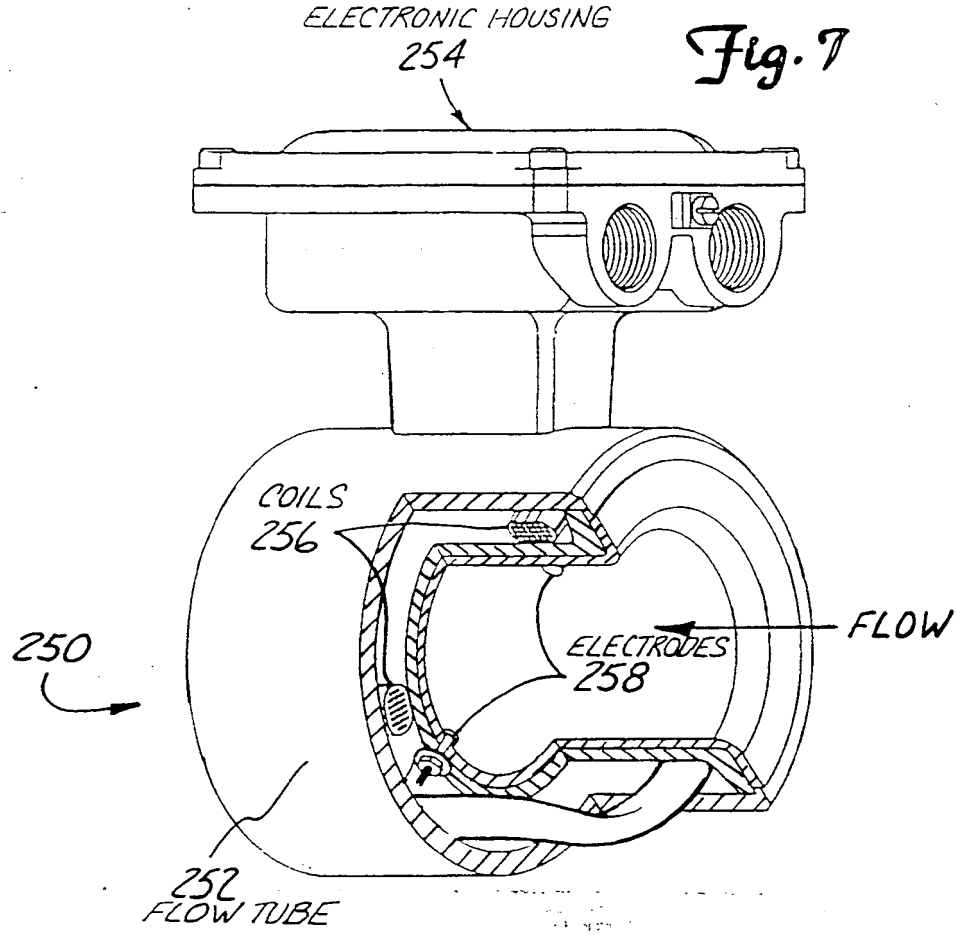

Fig. 7

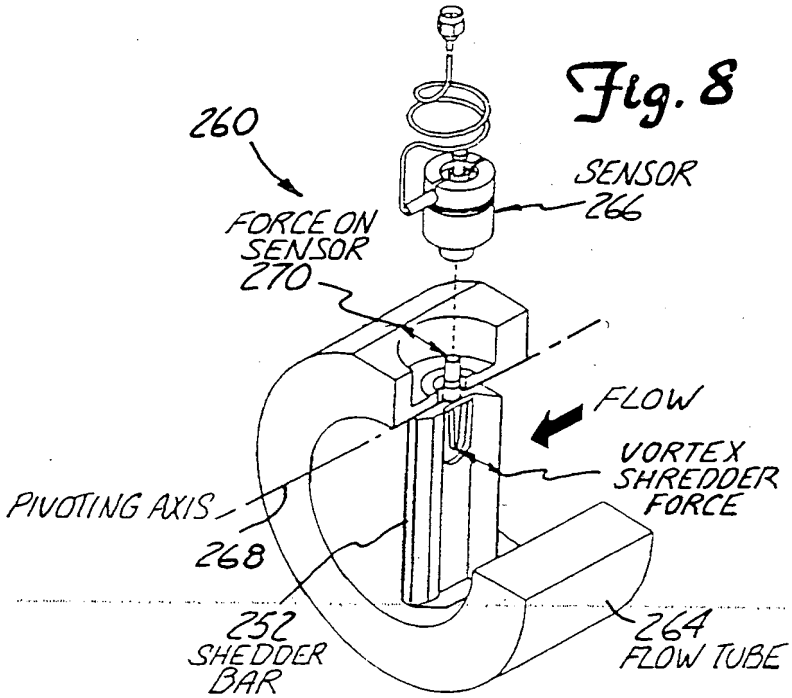

Fig. 8

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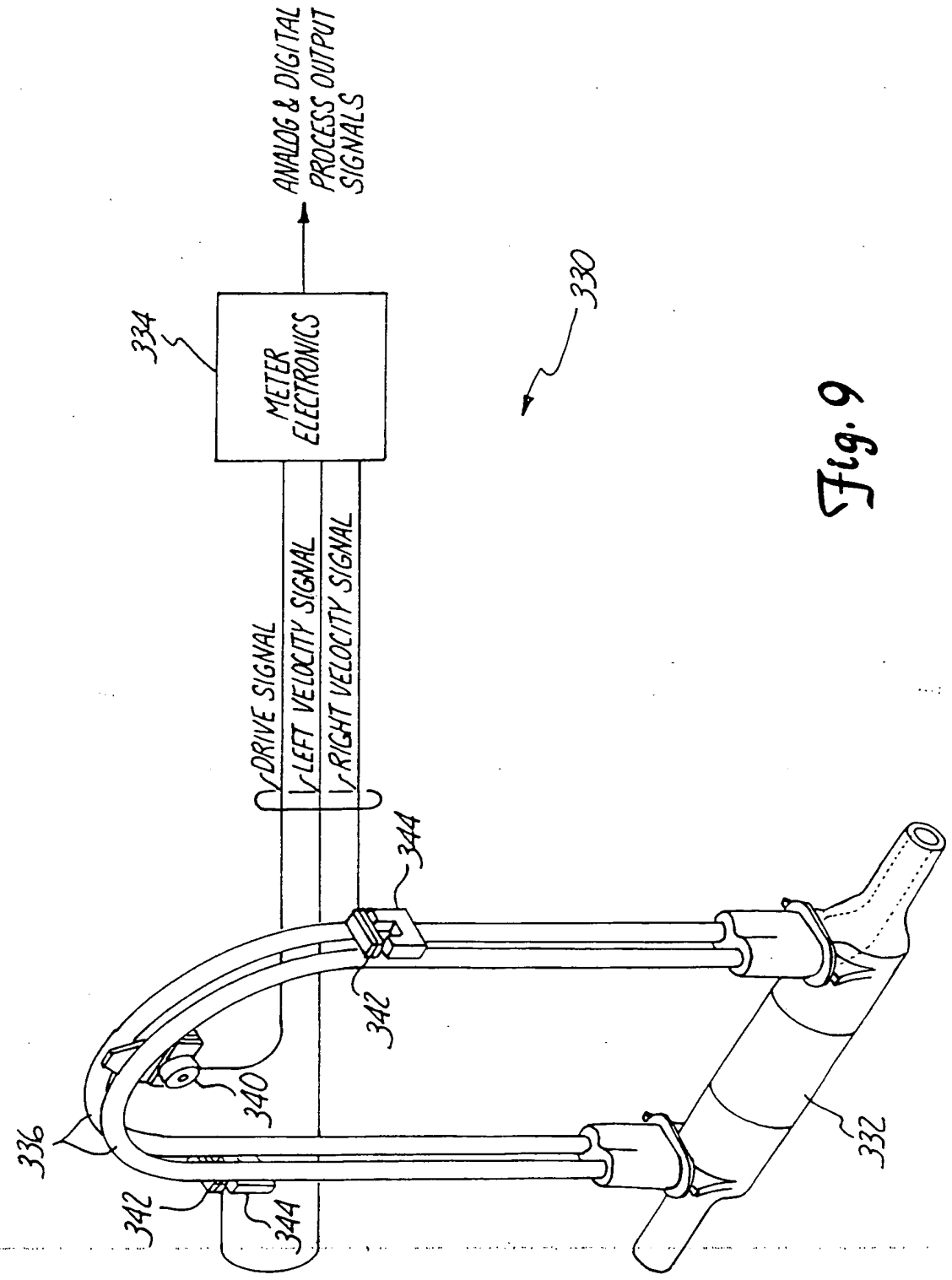

Fig. 9

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/ .. 00/14798

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G05B23/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
PAJ, EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 1997, no. 01, 31 January 1997 (1997-01-31) & JP 08 247076 A (MATSUSHITA REFRIG CO LTD), 24 September 1996 (1996-09-24) abstract ---	1,3,25, 41-46
X	PATENT ABSTRACTS OF JAPAN vol. 011, no. 208 (P-593), 7 July 1987 (1987-07-07) & JP 62 030915 A (MITSUBISHI HEAVY IND LTD), 9 February 1987 (1987-02-09) abstract ---	1,3,25, 41-46
X	WO 97 21157 A (HONEYWELL, INC.) 12 June 1997 (1997-06-12) the whole document -----	1,3,25, 41-46

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Date of the actual completion of the international search	Date of mailing of the international search report
28 September 2000	04 10. 2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Van Assche, P

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INTERNATIONAL SEARCH REPORT

mation on patent family members

International Application No
PCT, US 00/14798

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